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The primary objective of the digital sensor simulation investigations being conducted at the Defense Mapping Agency (DMA) is to establish an editing and analysis capability for the digital culture and terrain data bases. These data bases are being produced by DMA to support advanced aircraft simulators by providing an improved high, medium, and low level radar training capability offered by the digitally generated radar landmass images.

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In addition to radar scenes, visual and multi-sensor scenes are being digitally generated. For purposes of quality control and data base applicability investigations, DMA has developed the Sensor Image Simulator (SIS), a very high speed data base edit station and static scene simulator that allows for interactive query and manipulation of individual features in the data base displays and/or simulated sensor scenes to determine the corresponding data base elements responsible for the simulated features. The SIS was installed at DMA in 1981, and has been used to support studies, such as the applicability of synthetically enhanced data bases for the Tornado simulator, synthetic aperture radar simulations to support Space Shuttle experimentation, advanced color analysis of simulated radar scenes, and development of a low resolution interim data base for use in high altitude, long range, radar simulation.

SENSOR IMAGE SIMULATOR APPLICATION STUDIES

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ABSTRACT

The primary objective of the digital sensor simulation investigations being conducted at the Defense Mapping Agency (DMA) is to establish an editing and analysis capability for the digital culture and terrain data bases. These data bases are being produced by DMA to support advanced aircraft simulators by providing an improved high, medium, and low level radar training capability offered by the digitally generated radar landmass images.

In addition to radar scenes, visual and multi-sensor scenes are being digitally generated. For purposes of quality control and data base applicability investigations, DMA has developed the Sensor Image Simulator (SIS), a very high speed data base edit station and static scene simulator that allows for interactive query and manipulation of individual features in the data base displays and/or simulated sensor scenes to determine the corresponding data base elements responsible for the simulated features. The SIS was installed at DMA in 1981, and has been used to support studies such as the applicability of synthetically enhanced data bases for the Tornado simulator, synthetic aperature radar simulations to support Space Shuttle experimentation, advanced color analysis of simulated radar scenes, and development of a low resolution interim data base for use in high altitude, long range, radar simulation.

INTRODUCTION

The primary objective of the digital sensor simulation investigations being conducted at the Defense Mapping Agency (DMA) is to establish an editing and analysis capability for the digital culture and terrain data bases. These data bases are being produced by DMA to support advanced aircraft simulators by providing an improved high, medium and low level radar training capability offered by the digitally generated radar landmass images. As a result of the technology developed for the aircraft simulator support, sensor guidance reference scenes are also being generated.

In addition to radar scenes, visual and multi-sensor scenes are being digitally generated. For purposes of quality control and data base applicability investigations, DMA has developed the Sensor Image Simulator (SIS), a very high speed data base edit station and static scene simulator that allows for interactive query and manipulation of individual features in the data base displays and/or simulated sensor scenes to determine the corresponding data base elements responsible for the simulated features (see Figure 1). The SIS was installed at DMA in 1981, and plays a key role in determining the applicability of prototype data bases for use in advanced training simulators, as well as to ensure the quality of, and coherence between, the various digital data bases prior to new data insertion into the master cartographic data base files.

DATA BASE CONTENT

The current DMA standard production data bases (Level I) contain large area cultural information and digital terrain data sampled at a 3" interval. The cultural data consists of point, linear, and areal features described by characteristics such as surface material category, generic identification, predominant height, structure density, and percentages of roof and tree cover. The cultural data is in lineal (planimetric boundary) format and, although feature sizes may vary depending upon local circumstances, reflects a resolution on the order of 500 feet. Smaller features are aggregated into homogeneous features described by predominant characteristics. The current high resolution (Level II) data bases contain small area cultural information and digital terrain elevation data sampled at 1" interval. This translates to a resolution of about 100 feet, with smaller features aggregated. Detailed information is available in "Product Specifications for Digital Landmass System (DLMS) Data Base" (1).

The terrain elevation data is produced by contour digitization from charts or directly from stereo pairs of photographs using advanced analytical stereoplotters. The cultural data is produced from both charts and photographs with a much higher level of manual effort required in order to perform the complex feature analysis. Because of the labor task intensive nature of the tak, the production of Level II cultural data ranges from 10 to 50 times the production cost of Level I data, depending upon the area. The current Level I data base program covers roughly 24 million square nautical miles, with estimated data base completion dates in the 1985 to 1998 time period. Level II data is programmed only for small selected areas of interest.

The DLMS data bases have been shown to be adequate for support of long and medium range radar simulation, and for short range radar simulation where Level II data is available. In addition, these data bases have shown some applicability for multi-sensor simulation (2,3).

THE SIS CONCEPT

The natural evolution of sensor simulation at DMA led to the design and fabrication of the Sensor Image Simulator (SIS), a dedicated mini-computer-based image processing system capable of performing simulations in an interactive mode.

The Sensor Image Simulator performs five major functions:

1. Digital Data Base File Input and Output.

2. Off-line to On-line Data Base Transformation.

3. Sensor Simulation.

4. Interactive Data Base Editing.

5. Software Development and Maintenance.

Detailed information on SIS operations, hardware, and software has been previously published (4).

Figure 1. The Sensor Image Simulator

SPECIAL APPLICATION STUDIES

The SIS has been used to support studies such as the applicability of synthetically enhanced data bases for the Tornado simulator, synthetic aperature radar simulations to support Space Shuttle experimentation, advanced color analysis of simulated radar scenes, and development of a low resolution interim data base for use in high altitude, long range radar simulation.

Tornado Support

With the development of advanced high resolution radar and visual simulators, higher resolution cultural data bases are required. Production resources limit this higher resolution data to small geographic areas of interest, and worldwide coverage is unattainable without automated feature extraction techniques. Due to the extremely high production cost for very high resolution off-line data bases, techniques have been developed to simulate high resolution on-line data bases from lower resolution off-line input, and then to generate the simulated sensor scenes from the synthetic data base. Results have shown a high degree of success associated with enormous cost savings and the appearance of greater resolution in the simulation of those areas for which the requirement for realism supersedes that of precise geometric fidelity.

The Level I data base aggregates Level II type information into homogeneous areal features with associated predominant descriptors, including percentage tree and roof cover. The synthetic feature break-up technique generates random cultural, tree cover, and background features within the areal feature boundaries, based on the percentages of tree and roof cover. Cultural descriptors are then randomly assigned with a normal distribution about the predominant values of the original areal features. The Level II data also contains aggregate areal features of very high resolution, and the synthetic break-up process may be applied to any level of data. This type of synthetic feature break-up allows for greater realism for Level I simulation as well as the blending of actual Level II data patches within a Level I data base.

At the request of the United Kingdom (UK), the DMA investigated the applicability of this synthetic break-up process for use in Tornado simulator training. SIS radar modules were adjusted to reflect Tornado characteristics, and a series of simulations were performed with and without synthetically enhanced Level I data over the UK. An example of the results ~~are~~ shown in figure 2. The UK is currently evaluating the results of these
IS studies.

Space Shuttle Support

At the request of the NASA Astronaut Office, DMA has provided digital terrain elevation and feature data for mission planning of future Shuttle Imagery Radar (SIR) experiments. Primary areas of interest were over parts of Alaska and the Rio Grande rift. The objective was to predict what the SIR would see prior to actual experimentation. DMA modelled a simplified version of the SIR parameters and u~~t~~tilized the Synthetic Aperature Radar (SAR) simulation capability of the SIS. A subset of the data utilize base supplied to NASA and resulted SIS simulations are shown in figure 3. Future efforts are to evaluate comparisons with actual SIR scenes of these areas after the mission.

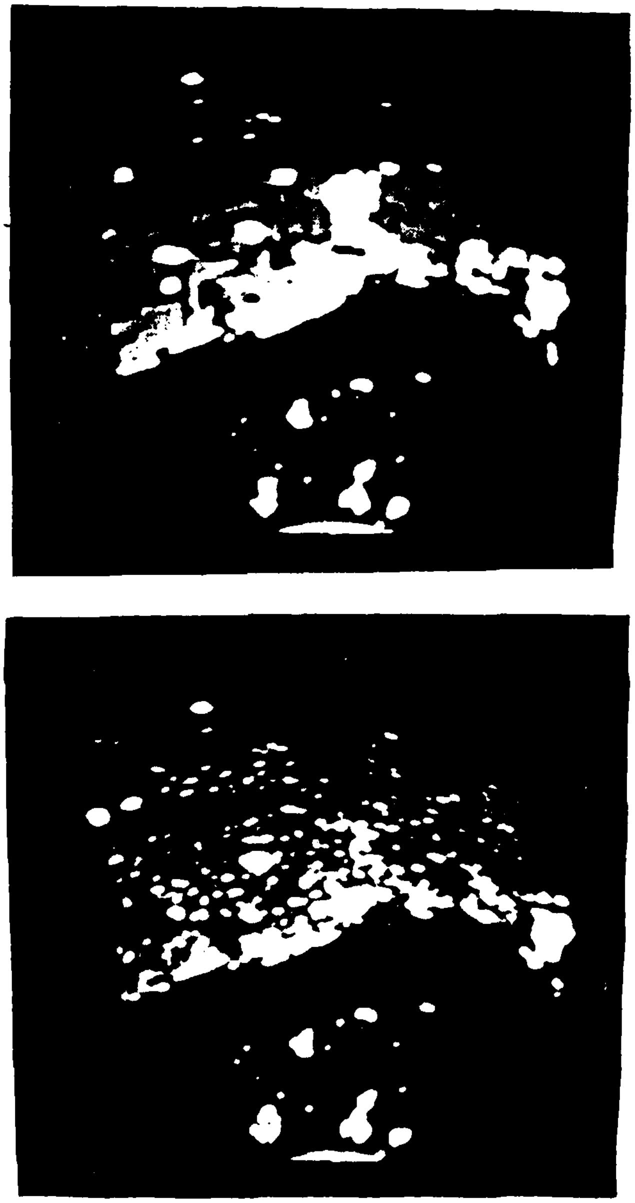

Figure 2. Tornado Radar Simulations with and without synthetic break-up

Simulation here

Figure 3. Space Shuttle Suppport:
Albuquerque and the Rio Grande Rift:
Data Base and SIR Simulations.

Advanced Color Analysis

One of the primary functions of the SIS is to serve as a tool for requirements analysis of the digital data bases to support simulator systems. In addition to the ability to program mathematical algorithms to simulate various radar electronics, the SIS has the capability for interactive radar set parameter variation via joystick control.

One such example is to vary the amount of beam width error (BWE) in the radar set. As BWE increases, brighter features tend to blend together and "no-show" areas such as water and radar shadows are diminished in size. The spreading of the response on the radar display also exhibits decreasing intensity as a function of angular distance from the original feature. Because of inability of the human eye to detect subtle intensity changes, which are often compounded by the interaction of BWE from multiple features, the SIS has been programmed to display color radar in addition to monochrome.

With the proper color table to intensity assignment, the color radar display has shown to be advantageous for analysis of the radar returns. Especially noticeable are the separations of bright returns of slightly different intensities and the ability to see the effects of increasing BWE.

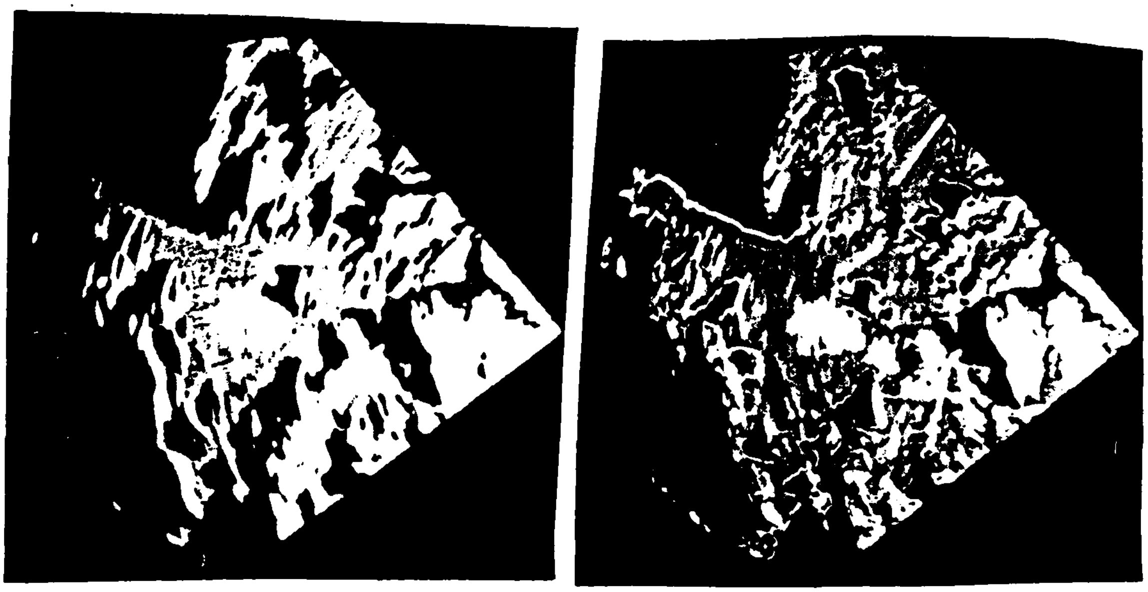

Figure 4. Monochrome and Color Radar (B&W image) Displays

Interim Data Base Analysis

Because of the vast requirement for DLMS data, and the projected completion dates, DMA has been investigating the generation of an interim low resolution data base intended for use in high altitude, long range, radar simulation. This data base would not meet all the specifications of DLMS Level I data, but would serve to fill gaps in the data base until corresponding Level I data is produced.

The production scenario consists of automated processing of landscape features using LANDSAT multi-spectral imagery, and interactive outlining of urban areas using existing charts as guides for locating the urban areas on the LANDSAT scenes. The urban areas are then assigned typical DLMS attributes. Preliminary investigations have been accomplished by producing this data on the DMA Digital Interactive Multi-Image Analysis System (DIMIAS) with subsequent analysis and radar simulation on the SIS. Figure 5. is a composite of the LANDSAT scene, the unfiltered automatic landscape classification, the urban definition on the LANDSAT scene, and the final DLMS interim data base over Las Vegas, Nevada. The cost of producing this data base is only about 10% of the Level I.

Figure 5. Las Vegas Interim Data Base

Figure 6 shows a comparison of a long range (85 n.m.), high altitude (16,000 ft.) radar simulation over this area for both the Level I and interim data bases. Notice the high degree of similarity when urban feature break-up is not significant. For shorter range simulations, synthetic break-up of the interim data base could give the appearance of Level I data, but as stated earlier, could not provide precise geometric fidelity with the urban boundary.

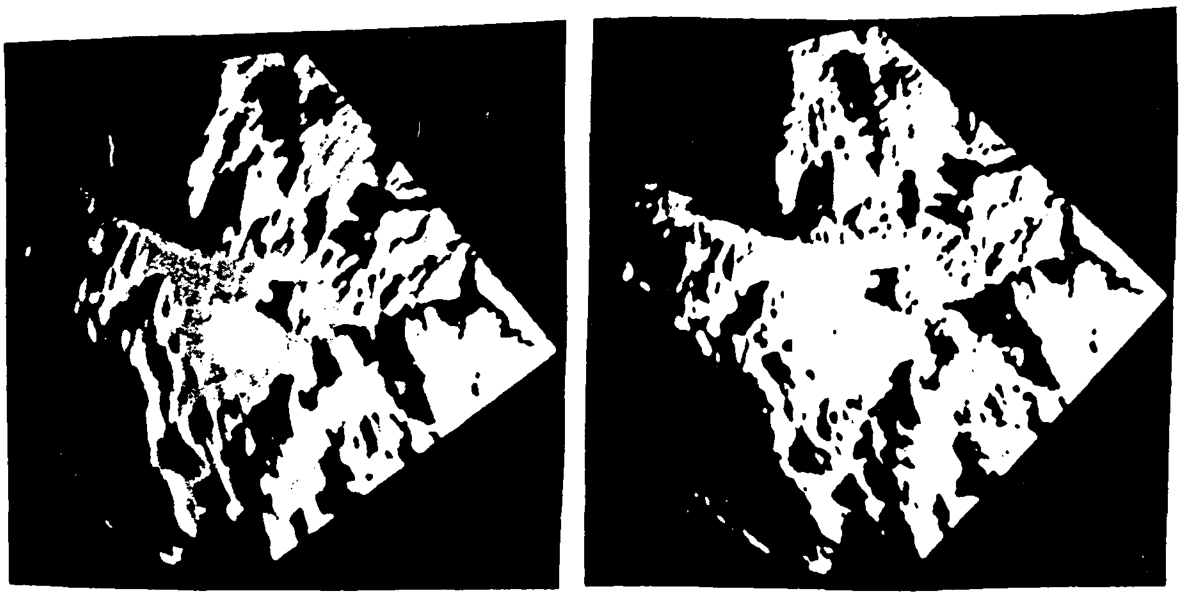

Figure 6. Level I versus Interim Data Base Simulations

CONCLUSIONS

In addition to quality control of the DMA digital data bases, the SIS has been shown to be a very useful tool for data base requirements analysis, and has given DMA the capability to predict the effectiveness of both future sensors and the suitability of the digital data bases that support them.

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